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EVALUATION OF A CHARGED WATER SPRAY SYSTEM FOR RADIATION CONTROL PURPOSES IN A HARD ROCK UNDERGROUND URANIUM MINE

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by

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ABSTRACT

A charged water spray system has been evaluated for the purpose of controlling radon progeny and airborne long-lived radionuclides in underground uranium mine atmospheres. Tests were conducted at different test sites. The data reported here were obtained in a crusher/conveyor belt area of a hard rock uranium mine. The effect of the charged water spray was found to be only marginally significant. The poor efficiency of the system is partly ascribed to low air residence time in the mine gallery, to an insufficient number of charged spray units, and to poor mine air mixing with the water mist.

In addition, it appears that the system was not operating at the proper current level, therefore the results are inconclusive.

Keywords: Water spray; Electrostatic precipitation; Radon daughters.

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ÉVALUATION D'UN SYSTÈME DE PULVÉRISATION D'EAU DANS LE BUT DE CONTRÔLER LES RAYONNEMENTS DANS UNE MINE D'URANIUM SOUTERRAINE EN ROCHE DURE

par

J. Bigu* et A. Frattini**

RÉSUMÉ

On a étudié un système de pulvérisation d'eau dans le but de contrôler les produits de filiation du radon et les radionucléides de longue période aéroportés dans l'atmosphère d'une mine d'uranium souterraine. L'étude a été effectué à différents sites d'essais. Les données recueillies lors de ces études ont été obtenues autour d'un convoyeur/broyeur d'une mine d'uranium en roche dure. On a réalisé que l'effet du système de pulvérisation d'eau n'est que marginalement significatif. Le faible rendement du système est attribuable, en partie, au court temps de séjour de l'air dans la galerie de la mine, au nombre insuffisant de pulvérisateurs chargés et enfin, au pauvre mélange d'air procuré par le brouillard d'eau dans la mine.

Il semble, en outre, que le système ne fonctionnait pas au niveau de courant indiqué, par conséquent les résultats de cette étude sont peu concluants.

Mots-clés: Pulvérisation d'eau; Précipitation électrostatique; Produits de filiation du radon.

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INTRODUCTION

A variety of techniques have been used, or proposed, to control dust emissions in mines, mills and other working environments. Techniques that have effectively been used in dust suppression include mechanical filtration, the use of wet scrubbers, electrostatic filtration employing filters with electret-like properties, hydraulic water sprays, electrostatic precipitation, and dust 'curtains' using fans. More recently, the use of electrostatic fog techniques have been suggested and applied (1).

Water sprays are effective in removing respirable dust from working atmospheres, and also in producing dust stratification for dust avoidance (2). However, charged water sprays should in principle be more efficient at dust suppression than traditional hydraulic sprays. Unlike hydraulic sprays, however, charged water sprays require a minimum residence time for the charged water droplets and the dust particles to interact. Charged water sprays are most effective where air exchange and air velocities are low (3). The use of electrostatic fog techniques, i.e., charged sprays, has met with success as reported by several authors (1,3,4).

In underground uranium mines and mills, radon gas and its short-lived decay products (i.e., radon progeny), and long-lived radionuclides are found in air in quite significant amounts. These radioactive products attach themselves to particulate matter in the submicron size range, and to dust in the respirable range and coarser dust. Long-lived radionuclides are found as part of dust material generated in the course of mining and milling operations, particularly in rock crushing and ore transportation operations.

Because of the association of radionuclides and airborne particulate matter, it suggests itself that an effective dust control technique may also be a good radiation control method. With this idea in mind, experiments have

been conducted to verify this contention. The present study emphasizes the radiation aspect of the problem.

Work on the use of a commercial charged water spray system was carried out in an underground uranium mine and in an uranium mill. Working locations were chosen compatible with the potential application of the charged water spray, i.e., areas of lowest air velocity, and hence, longest residence time, and large dust production, such as rock fragmentation and ore transportation operations. An ore conveyor belt in a mill and two crusher/conveyor belt areas in an underground uranium mine were chosen for this investigation.

EXPERIMENTAL PROCEDURE

The main objective of the study was to measure the concentration of:

i) Dust (coarse and respirable);

ii) Short-lived radon progeny associated with submicron particulate matter;

iii) long-lived radionuclides associated with dust;

Experimental tests were conducted in three conditions:

a) no water spray;

b) uncharged water spray; and

c) charged water spray.

Coarse and respirable dust data are reported elsewhere (5). Radon progeny was measured by grab-sampling using the Thomas-Tsivoglou method (6), an automated personal α-particle dosimeter (alpha-PRISM, from alpha-NUCLEAR, Toronto), and two Working Level (WL) continuous monitoring systems model RGA 400, manufactured by EDA Instruments (Toronto). Long-lived radionuclides associated with dust, i.e., Long-Lived Radioactive Dust (LLRD), was measured in dust samples collected with five 4 L/min respirable dust samplers, and two 2-stage, 30 L/min, dust samplers (5). In addition, respirable dust was continuously monitored with an automatic real-time dust monitor, Mini-Ram

model PDM-3 from Hoskins (U.S.A.).

Two radiation sampling stations were established, one before the water spray system, and the other some distance away downstream. Dust samplers for LLRD measurements were positioned at different locations before and after the water spray system. Instrumentation after the water spray system was positioned at variable distances to vary the air residence time. Two charged water spray units were used in close proximity.

Radon progeny data were collected every hour. Respirable dust data measured with the Mini-Ram were collected at a rate of one reading every six seconds. One dust sample, for LLRD analysis, was obtained per day and per sampler. Hence, 7 samples/day for LLRD measurement were available. In each case, the duration of the tests ranged from one to three weeks. Temperature (T) and relative humidity (RH) conditions underground were approximately: T ~14^{o}C, RH >85%, respectively.

THE CHARGED WATER SPRAY GENERATORS

The charged water spray generators used in the tests are manufactured by Keystone Dynamics (Villanova, PA, U.S.A.), and they are known under the commercial name DUSTRON Series 100.

The primary component of the system is the DUSTRON emitter. This unit uses compressed air to generate a finely atomized water mist. As the water is atomized, electrostatic charges are placed on the water droplets. The DUSTRON emitter must be supplied with pressure-controlled compressed air and clean water at a given constant flow-rate. The DUSTRON emitter unit requires a 24 V DC power supply to energize the charging system. Water droplets are charged by the field produced by a high voltage coil in an insulated enclosure system. A control panel is used to meter the water flow-rate to each emitter, and to control air pressure.

In addition to the DUSTRON emitter and the control panel, the charged water spray generator is provided with an electrical power supply cabinet to generate the required 24 V DC for the emitters from a regular 115 V AC 50-60 Hz source.

The compressed air pressure to the water spray atomizers was regulated to approximately 400 kPa. The water inlet was regulated to about 70 kPa. The water flow-rate in each spray was in the range 0.076 to 0.30 L/min. However, different operating conditions were selected consistent with the specifications and range of operating values for the above variables suggested by the manufacturer.

No means to check whether the charged spray units were charging the water droplets were provided by the manufacturer or built-in in the spray system. The charging performance of the system had to be checked externally by measuring the electrical current in the water mist produced. This was done by means of a 20 cm x 20 cm metal mesh (~1 mm spacing) mounted on an insulated teflon rod and connected to ground through a multimeter. Under continuous operation the current measured was about 0.2 μA. This current was much lower than that according to the manufacturer (~5 μA) for optimum performance. A brief discussion on this item is deferred to the conclusions section.

TEST SITES

Preliminary tests were conducted in a surface conveyorway in a uranium mill. However, high air flows, and hence short residence times, and significant air leakage rendered little value to these experimental tests.

Subsequent to the uranium mill surface conveyorway location, an underground site in an underground hard rock uranium mine was chosen. The site was on a 110 m length of a 3.5 m x 3.0 m gallery containing a main conveyor belt carrying fragmented uranium ore from a main crusher installation

upstream. The air velocity in this location was about 1.8 m/s. The residence time between the charged water spray system and the downstream sampling location was approximately 45 sec. However, it became apparent that this residence time was also too short for proper mixing of dust with the water spray system. For this reason, a different underground location was selected where the bulk of the tests were carried out.

The second underground test location was a 4 m x 3 m, 66 m long gallery. The dust source in this case was the outlet of a filter installed on the crusher referred to above. The air flow in the gallery was approximately 0.3 m/s, and the residence time between the last sampling station and the charged water spray systems was about 130 sec. In order to increase the local air velocity and improve mixing of the air, brattice was hung in the test gallery. The experimental layout of the test location is shown in Figure 1.

EXPERIMENTAL RESULTS AND DISCUSSION

The results obtained have been summarized in Tables 1 to 4. Although a great deal of data were collected at the three experimental sites where measurements were carried out, only data pertaining to the last underground test location are presented here. The reason for this, as indicated above, is quite simple: experimental conditions in the last test location were by far the most favourable ones for the charged water spray system to operate according to expectations, namely longest residence time and best air mixing conditions.

Table 1 shows grab-sampling data mostly taken at position 4 (see Figure 1), i.e., past the charged water spray system. This table shows the variability of several variables of interest from day to day. Variations in the value of those variables could not be correlated to the operation of the charged water spray.

Data from the two RGA-400 radon progeny continuous monitoring systems and the alpha-PRISM do not show any significant difference between radiation levels at positions 1 and 4 that could not easily be attributed to the operation of the crusher and conveyor belt carrying the crushed ore, or to changes in airflow through the gallery.

Table 2 shows data obtained with two high flow-rate (~30 L/min) dust samplers located before and after the charged water spray system. The table shows the operating conditions of the spray system, the sampling time, the dust mass collected, and the long-lived radioactivity associated with the dust, measured a few weeks after the samples were collected. This delay time was necessary to allow the short-lived radioactivity from the radon and thoron progeny to decay away. The tables also show the activity ratio, and the dust mass ratio corresponding to each pair of samples, and the specific activity corresponding to each sample. The above ratios are taken as the ratio of the activity, or dust mass, of the downstream sample (i.e., after the spray system) to the upstream sample (i.e., before the spray system).

The data of Table 2 indicate that in all cases the activity and dust mass measured on the downstream samples were lower than that corresponding to the upstream samples. However, the differences observed were slightly larger when the charged water system was operating than when the system was idle. The differences measured were at most 10% and subject to significant measurement errors because of the low activity of the samples. One may conclude from these data that although the charged water spray seemed to have an effect on the long-lived radionuclide levels associated with the dust collected, this effect was not very significant.

Table 3 shows a similar type of data to that of Table 2 but collected with five respirable dust samplers operated at about 4 L/min. The results from this table are far less conclusive that those of Table 2. On average, no

significant difference was found using the respirable dust samplers. One tentative conclusion is that the charged water spray was more effective in removing long-lived radionuclides associated with coarse dust than with respirable dust. However, this contention cannot be verified on the basis of the data presented here.

Table 4 shows respirable dust concentration data obtained with the Mini Ram 'real-time' continuous dust monitor. Large variations in dust concentration can be seen. The abrupt increases in dust concentration observed roughly coincide with the operation of the crusher and conveyor belt carrying crushed ore for further processing. No differences in dust concentration could be attributed to the operation of the charged water spray system.

CONCLUSIONS AND REMARKS

The effect of a charged water spray on the concentration of long-lived radionuclides associated with dust in the respirable range and coarser dust was only marginal. No significant difference could be found for respirable dust. Only a very small effect (<10%) could be observed for total dust, i.e., respirable dust plus coarser dust. There seems to be little doubt that results could have noticeably been improved by operating more charged spray units at the cost, however, of a considerable increase in unwanted underground fogging conditions.

Broadly speaking, the above findings roughly agree with detailed dust studies conducted during the same tests (5). Furthermore, respirable dust concentration measurements carried-out with the Mini Ram failed to show any difference that could be attributed to the operation of the charged water spray. The same holds true for radon progeny measured by grab-sampling and three continuous monitoring systems. From radon progeny data (see Table 1)

one may also conclude that the charged water spray system had little effect on particulate matter in the submicron range. (It should be noted that radon progeny is preferentially attached to submicron aerosol.)

From the data presented in this report, it may be concluded that the experimental effects observed are not enough to encourage the use of charged water spray systems for radiation control application, although they may prove of more value for dust suppression purposes. The system would undoubtedly have performed better under different experimental conditions, such as more thorough air mixing and much longer air residence time, conditions which are not always met at working locations in underground mines.

An observation is worth mentioning. The assumption was made that the charged water spray system was operating according to specifications, i.e., about 5 μA. However, the current was only checked at the end of the underground tests, and found to be much lower, i.e., 0.2 μA (5), than optimum operating conditions. It is not known whether optimum conditions were attained at any point in the experiments. However, when the system was tested in the laboratory such a current could be observed for a period of time after which a slight current decrease could be noted.

It is not clear whether this decrease in current was caused by a deterioration of the operating condition of the spray system or to the soaking of the electrostatic probe. Furthermore, it was noted that although the pilot light of the filament unit was on, there was no guarantee that the cable from the power supply to the filament unit was properly connected, and hence providing power to the unit. In fact, on more than one occasion, when the system was tested, no current, or a very low current, could be measured. However, when touching the supply cable and pressing against the socket, proper contact could be reestablished. We find this to be an important deficiency which should be eliminated altogether.

In view of the above, our conclusion should perhaps be slightly modified to indicate that the results presented here might have been obtained, on occasion, under reduced operating current conditions, and hence, under unfavourable conditions. Because of this, the merits of the system have not been established conclusively and further experimentation will be needed.

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Table 1 - Radon progeny data obtained by grab-sampling (Thomas-Tsivoglou method).

Date	Time	Location*	WL(Rn) (mWL)	$[^{218}Po]$ (pCi/L)	$[^{214}Pb]$ (pCi/L)	$[^{214}Bi]$ (pCi/L)	$\frac{[^{214}Pb]}{[^{218}Po]}$	$\frac{[^{214}Bi]}{[^{218}Po]}$	Water Spray	Charged Water Spray	Water Feed Flow-Rate (L/min)
March 17/86	17:22	4	19.4	9.1	1.6	0.6	0.18	0.06	Yes	Yes	0.15
	17:54	"	22.9	10.4	2.3	0.2	0.22	0.02	"	"	"
	18:31	"	19.7	9.3	2.1	-	0.22	-	"	"	"
	19:04	"	17.9	7.6	1.5	0.6	0.20	0.08	"	"	"
March 18/86	17:27	4	14.8	3.7	1.3	1.1	0.35	0.30	No	No	-
	18.05	"	15.2	4.5	1.1	1.3	0.24	0.29	"	"	-
March 20/86	17:16	4	24.3	17.2	9.0	1.7	0.52	0.10	No	No	-
	17.52	"	27.8	17.5	11.2	2.9	0.64	0.17	"	"	-
March 21/86	17:15	4	17.9	5.3	1.5	1.3	0.28	0.24	Yes	No	0.15
	17:54	"	16.8	4.4	1.5	1.2	0.34	0.27	"	"	"
	18:26	"	17.7	6.8	1.5	0.8	0.22	0.12	"	"	"
	19:04	"	18.4	5.8	1.4	1.5	0.24	0.26	"	"	"
	19:38	"	20.3	6.0	1.7	1.5	0.28	0.25	"	"	"
March 24/87	17:05	1	10.8	6.2	0.7	0.2	0.11	0.03	Yes	Yes	0.076
	18:01	"	10.3	4.5	0.8	0.4	0.18	0.09	"	"	"
March 25/86	17:18	4	26.3	8.5	2.2	1.7	0.26	0.20	Yes	Yes	0.30
	17:48	"	26.4	9.9	2.3	1.3	0.23	0.13	"	"	"
March 26/86	17:18	1	15.6	7.1	1.1	0.7	0.15	0.10	Yes	Yes	0.30
	17:50	4	23.3	9.2	2.0	1.0	0.22	0.11	"	"	"
	18:21	"	19.0	6.7	1.4	1.3	0.21	0.19	"	"	"

* Positions 1 and 4 refer to before and after the charged water spray system, respectively.

Table 2 - Long-lived radioactive dust measurements on two stage (∿30 L/min sampling flow-rate) dust samplers.

Date	Sample No.	Location	Sampling Time (min)	Water Spray	Charged Water Spray	Water Feed Flow-rate (L/min)	Sample Activity (mBq)	Activity Ratio*	Dust Mass (mg)	Dust Mass Ratio*	Specific Activity mBg/mg
March 17/86	M	5	149	Yes	Yes	0.15	652.9		-	-	-
	N	6	"	"	"	"	608.6	0.93	-	-	-
March 18/86	O	5	63	No	No	-	301.0		6.05		49.7
	P	6	"	"	"	-	278.2	0.92	-	-	-
March 19/86	Q	5	75	Yes	Yes	0.15	592.7	-	4.43		133.8
	R	6	75	"	"	"	488.3	0.82	3.95	0.89	123.6
March 20/86	S	5	105	No	No	-	733.4		9.74		75.3
	T	6	"	"	"	-	699.9	0.95	9.20	0.94	76.0
March 21/86	U	5	188	Yes	No	0.15	592.7		7.24		81.9
	V	6	"	"	"	"	488.3	0.82	6.54	0.90	74.7
March 24/86	W	5	72	Yes	Yes	0.076	578.3		6.00		96.4
	X	6	"	"	"	"	530.0	0.92	5.51	0.91	96.2
March 25/86	Y	5	79	Yes	Yes	0.30	488.3		5.04		96.9
	Z	6	"	"	"	"	410.0	0.84	3.82	0.76	107.3
March 26/86	A	5	103	Yes	Yes	0.30	488.0		5.12		95.3
	B	6	"	"	"	"	419.8	0.86	3.99	0.78	105.2

Remarks: Positions 5 and 6 are before and after charger water spray system, respectively.

* Ratio of activity (mass) after and before the charged water spray system.

Table 3 - Long-lived radioactive dust measurements on respirable dust samples (samplers flow rate: 3.7 to 4.0 L/min)

Date	Sample No.	Location[1]	Sampling Time (min)	Water Spray	Charged Water Spray	Sample Activity (mBq)	Water Feed Flow-Rate (L/min)	Mean Activity Value* (mBq)	Mean+ Activity Ratio	Dust Mass (mg)	Mean* Mass Value (mg)	Mean+ Mass Ratio	Mean Spec. / Mean Mass (mBq/mg)
March 17/86	38	1	149	Yes	Yes	74.1	0.15	-		1.16	-		-
	39	1	"	"	"	88.9	"	81.5		1.15	1.15		70.9
	40	2	"	"	"	51.0	"	51.0		0.77	0.77		66.2
	41	4	"	"	"	75.6	"	-		1.03	-		-
	42	4	"	"	"	58.0	"	66.8	0.82	1.10	1.06	0.92	63.0
March 18/86	43	1	63	No	No	45.7	-	-		0.57	-		-
	44	1	"	"	"	26.9	-	36.3		0.58	0.57		63.7
	45	2	"	"	"	24.8	-	24.8		0.52	0.52		47.7
	46	4	"	"	"	41.2	-	-		0.58	-		-
	47	4	"	"	"	42.1	-	41.6	1.15	0.59	0.58	1.02	71.7
March 19/86	48	1	75	Yes	Yes	60.6	0.15	-		0.69	-		-
	49	1	"	"	"	54.1	"	57.3		0.60	0.64		89.5
	50	2	"	"	"	33.4	"	33.4		0.54	0.54		61.8
	51	4	"	"	"	46.7	"	-		0.64	-		-
	52	4	"	"	"	48.0	"	47.3	0.82	0.63	0.63	0.98	75.1
March 20/86	53	1	105	No	No	102.0	-	-		1.36	-		-
	54	1	"	"	"	99.6	-	100.8		1.36	1.36		74.1
	55	2	"	"	"	81.3	-	81.3		1.29	1.29		63.0
	56	4	"	"	"	109.9	-	-		1.46	-		-
	57	4	"	"	"	75.0	-	92.4	0.92	1.26	1.36	1.00	67.9
March 21/86	58	1	187	Yes	No	81.3	0.15	-		0.95	-		-
	59	1	"	"	"	83.2	"	82.2		0.93	0.94		87.4
	60	2	"	"	"	48.9	"	48.9		0.84	0.84		58.2
	61	4	"	"	"	63.8	"	-		0.91	-		-
	62	4	"	"	"	75.1	"	69.4	0.84	1.06	0.98	1.04	70.8
March 24/86	63	1	72	Yes	Yes	71.3	0.076	-		0.82	-		-
	64	1	"	"	"	73.4	"	72.3		0.76	0.79		91.5
	65	2	"	"	"	59.8	"	59.8		0.67	0.67		89.2
	66	4	"	"	"	60.7	"	-		0.82	-		-
	67	4	"	"	"	76.8	"	68.7	0.95	0.76	0.79	1.00	87.0
March 25/86	68	1	79	Yes	Yes	54.2	0.30	-		0.79	-		-
	69	1	"	"	"	55.4	"	54.8		0.74	0.76		72.1
	70	2	"	"	"	46.4	"	46.4		0.59	0.59		78.6
	71	4	"	"	"	57.1	"	-		0.65	-		-
	72	4	"	"	"	63.0	"	60.0	1.09	0.72	0.68	0.89	88.2
March 26/86	73	1	103	Yes	Yes	55.8	0.30	-		0.66	-		-
	74	1	"	"	"	56.9	"	56.3		0.76	0.71		79.3
	75	2	"	"	"	39.7	"	39.7		0.55	0.55		72.2
	76	4	"	"	"	56.9	"	-		0.79	-		-
	77	4	"	"	"	53.5	"	55.2	0.98	0.69	0.74	1.04	74.6

[1] Positions 1, 2 and 4 correspond to location before, at, and after the charged water spray system.

* Mean value of the samples at each location.

+ is the ratio of the mean value at position 4 to the mean value at position 1.

Table 4 - Respirable dust concentration measurements carried out with a real-time continuous dust sampler Mini Ram PDM-3. The instrument was located at position 4, i.e., downstream of charged water spray.

Date	Time	Dust Concentration (mg/m^3)	Water Spray	Charged Water Spray	Water-Feed Flow-Rate (L/min)
March 17/86	18:10	1.12±0.06	Yes	Yes	0.15
	18:30	2.6±0.03	"	"	"
	18:50	1.56±0.08	"	"	"
	19:30	2.04±0.09	"	"	"
March 18/86	15:30	0.79±0.04	No	No	-
	15:50	0.62±0.01	"	"	-
	16:10	0.62±0.01	"	"	-
	16:30	0.61±0.01	"	"	-
	16:50	0.62±0.01	"	"	-
	17:30	3.61±0.13	"	"	-
	17:50	2.18±0.08	"	"	-
	18:10	2.45±0.20	"	"	-
March 19/86	15:40	1.19±0.01	Yes	Yes	0.15
	16:00	1.22±0.01	"	"	"
	16:20	0.80±0.01	"	"	"
	16:40	0.82±0.02	"	"	"
	17:00	0.82±0.02	"	"	"
	17:20	3.59±0.08	"	"	"
	17:40	2.84±0.02	"	"	"
	18:00	2.47±0.07	"	"	"
March 20/86	15:38	0.22±0.01	No	No	-
	15:58	0.23±0.01	"	"	-
	16:18	0.24±0.01	"	"	-
	16:38	0.22±0.02	"	"	-
	16:58	0.21±0.02	"	"	-
	17:18	6.57±0.09	"	"	-
	17:38	5.84±0.31	"	"	-
	17:58	3.34±0.08	"	"	-
	18:18	2.02±0.03	"	"	-
	18:38	2.20±0.06	"	"	-
March 21/86	15:40	0.51±0.02	Yes	No	0.15
	16:00	0.61±0.01	"	"	"
	16:20	0.60±0.01	"	"	"
	16:40	0.63±0.01	"	"	"
	17:00	0.63±0.01	"	"	"
	17:20	2.09±0.02	"	"	"
	17:40	1.98±0.01	"	"	"
	18:00	1.06±0.01	"	"	"
	18:20	1.00±0.02	"	"	"
	18:40	1.32±0.04	"	"	"
March 24/86	15:50	0.69±0.02	Yes	Yes	0.076
	16:10	0.67±0.01	"	"	"
	16:30	0.66±0.01	"	"	"
	16:50	0.66±0.01	"	"	"
	17:10	0.67±0.01	"	"	"
	17:30	5.13±0.09	"	"	"
	17:50	3.64±0.11	"	"	"
	18:10	2.13±0.03	"	"	"
	18:30	1.02±0.01	"	"	"
March 25/86	15:30	0.93±0.03	Yes	Yes	0.30
	15:50	0.90±0.01	"	"	"
	16:10	0.89±0.01	"	"	"
	16:30	0.88±0.01	"	"	"
	16:50	0.89±0.01	"	"	"
	17:10	0.97±0.02	"	"	"
	17:30	4.06±0.07	"	"	"
	17:50	2.46±0.02	"	"	"
	18:10	1.89±0.06	"	"	"
March 26/86	15:30	1.89±0.02	Yes	Yes	0.30
	15:50	1.01±0.01	"	"	"
	16:10	1.0±0.01	"	"	"
	16:30	1.0±0.01	"	"	"
	16:50	1.0±0.01	"	"	"
	17:10	2.64±1.22	"	"	"
	17:30	3.37±0.08	"	"	"
	17:50	4.28±0.19	"	"	"
	18:10	2.49±0.34	"	"	"
	18:30	1.95±0.03	"	"	"

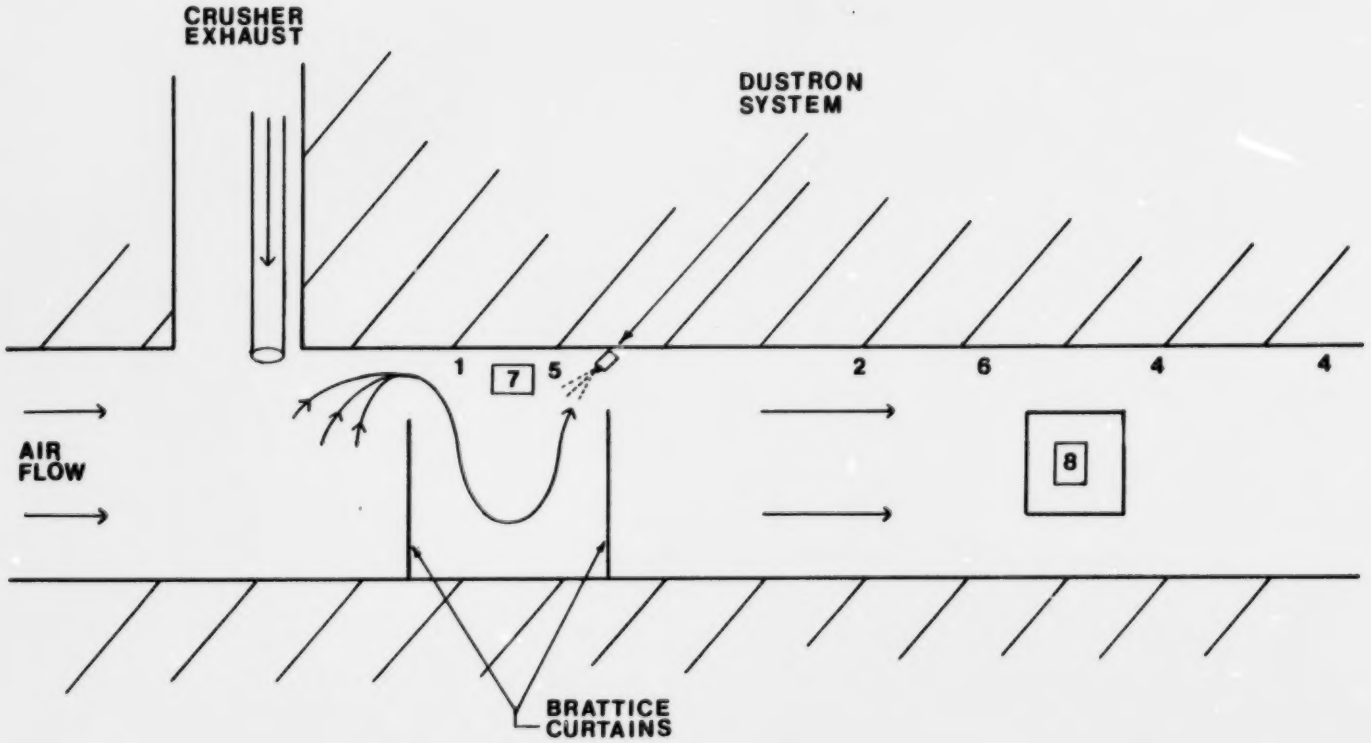

Fig. 1 - Experimental site. Numbers indicate locations where instrumentation was positioned. Positions 7 and 8 were used by the EDA RGA-400 continuous monitoring systems. Other locations are as indicated in the text.